TITLE OF THE INVENTION

METHOD OF DETECTING REPRODUCTION SIGNAL AND CIRCUIT THEREFOR

CROSS-REFERENCE TO RELATED APPLICATION

This application claims the benefit of Korean Application No. 99-40647, filed September 21, 1999, in the Korean Patent Office, the disclosure of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to detection of a reproduction signal, and more particularly, to a method of detecting only some of the outputs of an optical detection device, the detected outputs being least distorted or degraded, in an optical recording/reproduction system, and a circuit thereof.

2. Description of the Related Art

In the recording/reproduction system of optical recording media such as compact discs (CDs) and digital versatile discs (DVDs), data is manifested on a disc in the form of pits on a substrate or modifications of a recording film. Data on a disc is detected by illuminating the disc with a laser, and detecting light reflected back. In the recording/reproduction system, a signal is degraded due to a time delay between the outputs of an optical detection device. This

time delay may be caused by the geometry (for example, the width, the length, the depth and the angle) of a data pit and a recording domain. This time delay may also be caused by interference between data in a tangential direction. When a time delay is caused between the outputs of an optical detection device, a reproduction signal is distorted. When the amplitude of the reproduction signal is not properly detected, the performance of the system is degraded.

Optical discs are being developed for high-density recording and high-speed reproduction, to record and/or reproduce a high definition (HD) image. As recording/reproduction systems are developed for high-density and high-speed recording/reproduction, inter-symbol interference increases, causing time delays between adjacent data and distortion and deterioration of the signal. Accordingly, the performance of the reproduction signal is degraded, requiring considerable effort and extra cost during implementation of the system.

The prior art apparatus for reproduction signal detection is shown in FIG. 1. First, in order to detect information recorded on a disc 100, a pickup unit (P/U) 102 radiates a beam emitted from a light source (for example, a laser diode) to the disc 100, and a multi-section optical detection device 104 (which can also be called a detection sensor) receives and divides an optical signal reflected by the disc 100 into multiple signals. The optical optical detection device 104 is conventionally a photodetector (PD).

First, second, third and fourth current/voltage (IV) converters 106, 108, 110 and 112 convert current signals A, B, C and D output by the optical detection device 104 into voltage signals. An arithmetic unit 114 sums the voltage signals output by the first, second, third and

fourth IV converters 106, 108, 110 and 112, and outputs the sum as a radio frequency reproducing signal RF SUM.

In the prior art, a method of detecting a reproducing signal by simple addition of the outputs of the I/V converters 106, 108, 110 and 112 is adopted. Disadvantages of this method are that the reproducing signal is degraded due to the data conditions recorded on the disc, crosstalk, interference between optical signals reflected/diffracted from pits in close proximity to each other, from adjacent tracks on a recording medium, and from other problems with a system (for example, defocusing, detracking and tilting). Therefore, the quality of the reproducing signal and the performance of the system are degraded.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide a method of detecting a reproducing signal, by which only some of the outputs of an optical detection device, namely those that are the least degraded, are reproduced. Reproduction is based upon data conditions, the interference between optical signals reflected/diffracted from pits in close proximity to each other and from adjacent tracks on a recording medium, and/or the state of the system.

A second object of the present invention is to provide a method of detecting an optimal reproducing signal while overcoming problems caused by data conditions, crosstalk, and interference between optical signals reflected/diffracted from pits in close proximity to each other and from adjacent tracks on a recording medium.

A third object of the present invention is to provide a method of detecting an optimal reproducing signal while overcoming defocusing.

A fourth object of the present invention is to provide a method of detecting an optimal reproducing signal while overcoming detracking.

A fifth object of the present invention is to provide a method of detecting an optimal reproducing signal while overcoming radial tilting.

A sixth object of the present invention is to provide a method of detecting an optimal reproducing signal while overcoming tangential tilting.

A seventh object of the present invention is to provide a method of detecting an optimal reproducing signal by adaptively compensating for signal interference caused by data conditions, crosstalk, the interference between optical signals reflected/diffracted from pits in close proximity to each other and from adjacent tracks on a recording medium, defocusing, detracking, radial tilting and/or tangential tilting.

An eighth object of the present invention is to provide a circuit for detecting a reproducing signal, in which only some of the outputs of an optical detection device, namely those that are the least degraded, are reproduced. Reproduction is based upon data conditions, the interference between optical signals reflected/diffracted from pits in close proximity to each other and from adjacent tracks on a recording medium, and/or the state of the system.

Additional objects and advantages of the invention will be set forth in part in the description which follows, and, in part, will be obvious from the description, or may learned by practice of the invention.

To achieve the above and other objects of the present invention, there is provided a method of detecting a reproducing signal using an optical detection device to receive an optical signal reflected from an optical recording medium. The received signal is divided into multiple signals corresponding to sections of the optical detection device which are arranged in a matrix with rows in the tangential direction and columns in the radial direction of the optical recording medium. The method includes: (a) selecting some signals, namely those which are less degraded than other signals, from among the output signals of the optical detection device, the selection is based upon data conditions recorded on the optical recording medium, interference between optical signals reflected/diffracted from pits in close proximity to each other and from adjacent tracks on the optical recording medium, and/or various system states; and (b) obtaining a reproducing signal from the selected signals by compensating for the amount of signal interference caused by the data conditions, the interference between optical signals reflected/diffracted from pits in close proximity to each other and from adjacent tracks on a recording medium, and/or various system states.

To achieve the above and other objects of the present invention, there is provided a device to detect a reproducing signal using an optical detection device including photodetecting means to receive an optical signal reflected from an optical recording medium and dividing the received signal into multiple signals. The device includes a detector, a control unit, and a compensator. The detector detects the outputs of the optical detection device corresponding to a combination of signals corresponding to sections of the photodetecting means arranged in the tangential direction, the radial direction, and/or the diagonal direction. The control unit provides a selection control signal and a compensation signal on the basis of the results of

detection of data conditions recorded on the optical recording medium, the interference between optical signals reflected/diffracted from pits in close proximity to each other, and from adjacent tracks on the optical recording medium, and/or various system states. The compensator selects some of the outputs of the optical detection device provided via the detector in response to the selection control signal, and adaptively compensates for the selected outputs in response to the compensation signal.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other objects and advantages of the present invention will become more apparent and more readily appreciated from the following description of the preferred embodiments, taken in conjunction with the accompanying drawings of which:

FIG.1 is a block diagram illustrating the principle of conventional reproducing signal detection;

FIG. 2 is a circuit diagram of a reproducing signal detection circuit according to an embodiment of the present invention;

FIG. 3 shows an example of a 8-section photodetector that can be used as the optical detection device shown if FIG. 2;

FIG. 4 is a graph showing the results of detection of reproducing signals during detracking to explain the effects of the present invention; and

FIG. 5 is a graph showing the results of detection of reproducing signals during tangential tilting to explain the effects of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Reference will now be made in detail to the present preferred embodiments of the present invention, examples of which are illustrated in the accompanying drawings, wherein like reference numerals refer to like elements throughout.

Referring to FIG. 2, which shows a reproducing signal detection circuit according to an embodiment of the present invention, a pickup unit (P/U) 202 detects information recorded on a disc 200, and projects a beam emitted from a light source (laser diode) to the disc 200. An n-section optical detection device 204 receives and divides an optical signal reflected back from the disc 200 into multiple signals. Here, the optical detection device 204 groups multiple outputs into two parts by combining the multiple outputs in the radial direction, the tangential direction, or diagonally. The grouping depends on the data conditions, the interference between optical signals reflected/diffracted from pits in close proximity to each other and from adjacent tracks on the disc 200, or the state of a system (for example, problems with focusing, tracking, or tilting). Hence, the multiple outputs of the optical detection device 204 are grouped into degraded output signals and less degraded output signals. Using this characteristic, only the less degraded output signal group is reproduced depending on the state of the system, the data conditions or the interference between optical signals reflected/diffracted from pits in close proximity to each other and from adjacent tracts on the disc 200. Here, a signal used as a reproducing signal is automatically selected by a system state detector 226 to detect the state of a system (for example, focusing or defocusing, tracking or detracking, and tilting), the data conditions, or the interference between optical signals reflected/diffracted from pits in close proximity to each other and from adjacent tracks on the

disc 200. Some detection signals of the optical detection device 204, which are selected to compensate for abnormal operating conditions, detected data conditions, or detected interference between optical signals reflected/diffracted from pits in close proximity to each other and from adjacent tracks on the disc 200, are adaptively equalized, so that an optimal reproducing signal is detected.

That is, first, second, third and fourth current/voltage (I/V) converters 206, 208, 210 and 212 convert current signals A, B, C and D output by the optical detection device 204, into voltage signals. A first adder 214 adds a voltage signal output from the first I/V converter 206, to a voltage signal output from the second I/V converter 208, which corresponds to the output B of the optical detection device 204, and outputs the sum (A+B) as a signal R1. A second adder 216 adds a voltage signal output from the third I/V converter 210, which corresponds to the output C of the optical detection device 204, to a voltage signal output from the fourth I/V/ converter 212, which corresponds to the output D of the optical detection device 204, and outputs the sum (C+D) as a signal R2. Here, the outputs A and B of the optical detection device 204 have the same distance from the center of the disc 200, and the outputs C and D of the optical detection device 204 have the same distance from the center of the disc 200. A third adder 218 adds a voltage signal output from the first I/V converter 206, which corresponds to the output A of the optical detection device 204, to a voltage signal output from the fourth I/V converter 212, which corresponds to the output D of the optical detection device 204, and outputs the sum (A+D) as a signal T1. A fourth adder 220 adds a voltage signal output from the second I/V converter 208, which corresponds to the output B of the optical detection device 204, to a voltage signal output from the third I/V converter 210,

which corresponds to the output C of the optical detection device 204, and outputs the sum (B+C) as a signal T2. Here, the outputs A and D of the optical detection device 204 are on the same level in a tangential direction, and the outputs B and C of the optical detection device 204 are on the same level in a tangential direction. Accordingly, a time delay is generated between the output of the optical direction device 204 supplied via the third adder 218 and the output of the optical detection device 204 supplied via the fourth adder 220, in a tangential direction, due to data conditions, crosstalk, or the interference between optical signals reflected/diffracted from pits in close proximity to each other and from adjacent tracks on the disc 200. A fifth adder 222 adds a voltage signal output from the first I/V converter 206, which corresponds to the output A of the optical detection device 204, to a voltage signal output from the third I/V converter 210, which corresponds to the output C of the optical detection device 204, and outputs the sum (A+C) as a signal X1. A sixth adder 224 adds a voltage signal output from the second I/V converter 208, which corresponds to the output B of the optical detection device 204, to a voltage signal output from the fourth I/V converter 212, which corresponds to the output D of the optical detection device 204, and outputs the sum (B+D) as a signal X2. Here, the outputs of the fifth and sixth adders 222 and 224 are used when defocusing occurs, since they are obtained by adding diagonally-aligned outputs among the outputs of the optical detection device 204.

The system state detector 226 detects not only the system state (for example, defocusing, detracking and tilting) but also the data conditions and the interference between optical signals reflected/diffracted from pits in close proximity to each other and from adjacent tracks on the disc 200, and provides a selection control signal to a selector 228 so that at least

one good-performance signal is selected from among the outputs of the first through sixth adders 214 through 224 depending on a detected system state, detected data conditions and/or detected interference between optical signals reflected/diffracted from pits in close proximity to each other and from adjacent tracks on the disc 200. Also, the system state detector 226 calculates an adaptive equalization amount for compensating for the detected system state, the detected data conditions and/or the detected interference between data, and provides the adaptive equalization amount to first through sixth equalizers 230 through 240.

The selector 228 selects at least one signal from among the outputs of the first through sixth adders 214 through 224 in response to the selection control signal of the system state detector 226, and provides the selected signal to the corresponding first through sixth equalizers 230 through 240. The first through sixth equalizers 230 through 240 (EQ1 through EQ6) equalize the outputs of the optical detection device 204 selected by the selector 228 according to the adaptive equalization amount provided from the system state detector 226, thereby detecting an optimal reproducing signal.

Here, the first through fourth I/V converters 206 through 212, and the first through sixth adders 214 through 224 are referred to as detectors for detecting the outputs of the optical detection device 204 combined in the tangential direction, the radial direction, and diagonally. The system state detector 226 is referred to as a control unit for detecting the data conditions, the interference between optical signals reflected/diffracted from pits in close proximity to each other and from adjacent tracks on the disc 200, and/or various system states, and providing a selection control signal and a compensation signal on the basis of the results of the detection. The selector 228 and the first through sixth equalizers 230 through 240 can be referred to as a

compensator for compensating for unequal levels of some of the outputs of the optical detection device 204 supplied from the detector in response to the compensation signal (adaptive equalization amount) provided from the system state detector 226.

In the present invention, the selector 228 can be installed at the rear of the first through sixth equalizers 230 through 240, so that the signal having the best quality is selected as an optimal reproducing signal from among the equalized results RFR1, RFR2, RFT1, RFT2, RFX1 and RFX2 obtained by equalizing the signals R1, R2, T1, T2, X1 and X2 through first through sixth equalizers 230 through 240.

The detection of a reproducing signal when the system state detector 226 detects data conditions or the interference between optical signals reflected/diffracted from pits in close proximity to each other and from adjacent tracks on the disc 200, when it detects defocusing, when it detects detracking, when it detects radial tilting, and when it detects tangential tilting, will now be described on the basis of the operations of the selector 228 and the first through sixth equalizers 230 through 240.

(1) Detection of a reproducing signal depending on the data conditions or during the interference between optical signals reflected/diffracted from pits in close proximity to each other and from adjacent tracks on the disc 200.

As for a signal reproduced from data on the disc 200, one of the output signals T1 and T2 of the optical detection device 204 shown in FIG. 2 is less degraded than the other. The selector 228 selects one of the detected signals T1 and T2 in response to a selection control signal provided from the system state detector 226. The third or fourth equalizer 234 or 236, which receives the selected detected signal, equalizes the selected detected signal according to

the adaptive equalization amount that can compensate for the amount of signal interference caused due to the data conditions or the interference between optical signals reflected/diffracted from pits in close proximity to each other and from adjacent tracks on the disc 200, which are detected by the system state detector 226. In this way, an optimal RF reproducing signal is provided.

In the case of the optical detection device 204 used in FIG. 2, which is a four-section photodetector, track-directional sum signals A+D and B+C are represented as T1 and T2. However, the present invention is not limited to the four-section photodetector. In another embodiment, when the eight-section photodetector shown in FIG. 3 is used, T1 can indicate the sum of B1, B2, B3 and B4, and T2 can indicate the sum of A1, A2, A3 and A4.

(2) Detection of a reproducing signal upon defocusing

As for a signal reproducing from data on the disc 200, one of the detected signals X1 and X2 output by the optical detection device 204 is better than the other due to the direction of defocusing. The selector 228 selects the better quality signal from the detected signals X1 and X2 in response to a selection control signal provided from the system state detector 226. The fifth or sixth equalizer 238 or 240, which receives the selected detected signal, equalizes the selected detected signal according to the adaptive equalization amount that can compensate for the amount of signal interference caused due to the defocusing detected by the system state detector 226. In this way, an optimal RF reproducing signal is provided.

(3) Detection of a reproducing signal upon detracking

As for a signal reproduced from data on the disc 200, one of the detected signals R1 and R2 output by the optical detection device 204 is better than the other due to the direction of

detracking. The selector 228 selects one of the detected signals R1 and R2 in response to a selection control signal provided from the system state detector 226. The first or second equalizer 230 or 232, which receives the selected detected signal, equalizes the selected detected signal according to the adaptive equalization amount that can compensate for the amount of signal interference caused due to the detracking detected by the system state detector 226. In this way, an optimal RF reproducing signal is provided.

(4) Detection of a reproducing signal upon radial tilting

As for a signal reproduced from data on the disc 200, one of the detected signals R1 and R2 output by the optical detection device 204 is better than the other due to radial tilting. The selector 228 selects one of the detected signals R1 and R2 in response to a selection control signal provided from the system state detector 226. The first or second equalizer 230 or 232, which receives the selected detected signal, equalizes the selected detected signal according to the adaptive equalization amount that can compensate for the amount of signal interference caused due to the radial tilting detected by the system state detector 226. In this way, an optimal RF reproducing signal is provided.

(5) Detection of a reproducing signal upon tangential tilting

As for a signal reproduced from data on the disc, one of the detected signals T1 and T2 output by the optical detection device 204 is better than the other due to tangential tilting. The selector 228 selects one of the detected signals T1 and T2 in response to a selection control signal provided from the system state detector 226. The third or fourth equalizer 234 or 236, which receives the selected detected signal, equalizes the selected detected signal according to the adaptive equalization amount that can compensate for the amount of signal

interference caused due to the tangential tilting detected by the system state detector 226. In this way, an optimal RF reproducing signal is provided.

As described above, the n outputs of an optical detection device, which can be an n-section photodetector, are combined and grouped into two parts, depending on the data conditions recorded on a disc, the state of the interference between optical signals reflected/diffracted from pits in close proximity to each other and from adjacent tracks on a recording medium, or system states. When two signals obtained by the combination are compared, one detection signal is less degraded than the other. If two detected signals having opposite properties are simply combined, the characteristics of an inferior signal are included in the result, which prevents a good reproducing signal from being obtained.

To be more specific, when radial tilting occurs in the positive direction of a disc, the detected signal R1, which is one of the outputs of sections of the photodetector having the same distance from the center of the disc, is better than the detected signal R2, which is another signal output from sections of the photodetector having the same distance from the center of the disc. Conversely, when radial tilting occurs in the negative direction of the disc, the detected signal R1 is more degraded than the detected signal R2. The detected signal that improves the reproducing signal is selected from the two detected signals, in order to prevent degradation of the reproducing signal, resulting in an improvement in reproduction.

The effects of the present invention described above will now be described referring to FIGS. 4 and 5. In FIG. 4, which shows the results of detection of a reproducing signal during detracking, the jitter values of reproducing signals according to the present invention are compared to that in the prior art. Upon negative detracking, the detected signal R2 has less

jitter than the prior art and the detected signal R1. Thus, in this case, it is preferable that the detected signal R2 is used as a reproducing signal. Upon positive detracking, the detected signal R1 has less jitter than the prior art and the detected signal R2. Thus, in this case, it is preferable that the detected signal R1 is used as a reproducing signal.

For example, in the prior art, when a reproducing signal is detected using the sum of the outputs of a 4-section photodetector upon detracking within a range of +0.08 μm, jitter is about 15.6% (data to data). However, in the present invention, when the detected signal R2 is used upon detracking of -0.08 μm, jitter of about 9.22% is obtained. When the detected signal R1 is used upon detracking of +0.08 μm, jitter of about 9.22% is obtained, whereas jitter is approximately 15% in the prior art. Therefore, the present invention can obtain a reproducing signal having good characteristics and a wide margin, as compared to the prior art.

In FIG. 5, which shows the results of detection of a reproducing signal during tangential tilting, the jitter values of reproducing signals according to the present invention are compared to those of the prior art. Upon negative tilting, the detected signal T1 has less jitter than the prior art and the detected signal T2. Thus, in this case, it is preferable that the detected signal T1 is used as a reproducing signal. Upon positive tilting, the detected signal T2 has less jitter than the prior art and the detected signal T1. Thus, in this case, it is preferable that the detected signal T2 is used as a reproducing signal.

In the present invention, only some of the outputs of an optical detection device, namely those that are the least degraded, are used to reproduce a signal. Reproduction depends on the system states, the data conditions and/or the interference between optical signals reflected/diffracted from pits in close proximity and from adjacent tracks on a recording

medium. Thus, the jitter of a detected signal is improved, and the performance of the system can be improved.

Also, in the present invention, the demodulation degree of a signal, which is the most important factor in signal processing, is improved. Hence, signal distortion and signal degradation are reduced, and the performance of the system can be improved.

Furthermore, the use of a reproducing signal according to the present invention increases the defocusing margin, the detracking margin, the radial tilting margin, and the tangential tilting margin, so that the performance of the system can be improved.

Although a few preferred embodiments of the present invention have been shown and described, it would be appreciated by those skilled in the art that changes may be made in these embodiments without departing from the principles and spirit of the invention, the scope of which is defined in the claims and their equivalents.